Also we find here, in a noted cañon of ancient cliff-dwellings near San Francisco Mountains, a large *Cystopteris*, uniformly bearing bulblets near the apex of the fronds. If this is the species *C. bulbifera* it has not before been reported so far west as Arizona.

Fort Moroni, near Flagstaff, Ariz., July 30, 1884.

On the Sexuality of the Fungi.[1]

BY H. MARSHALL WARD.

I propose to show that it is probable that the sexuality of the higher Fungi has disappeared, because its purpose has been equally well or better attained otherwise than by means of sexual organs.

Preliminary to this it will be necessary to be quite clear as to what sexual organs and the sexual process essentially are.

The two points common to all the cases of sexual reproduction which have been directly observed are the following:

1. A larger or smaller quantity of protoplasmic material passes from one portion (the male organ) of the same or another individual, into the protoplasm contained in another portion (the female organ).

2. The protoplasm contained in the female organ therefore becomes capable of further development; either at once, or, more generally, after undergoing a period of rest.

It is not necessary to quote the numerous cases of observed analogies between the sexual reproduction of animals and plants; but will suffice to note that the essential in the sexual process is always the addition of a portion of protoplasm from the male, to the protoplasm of the female.

But this is not all. It is now well established in embryology that the normal ovum, or female mass of protoplasm, is incapable of further development until it has received the protoplasm of the male; that the latter, in fact, incites the former to further development.

The outcome of all we know of these matters leads to the conviction that we have in the germination or development of an

[1] The statement of the important hypothesis hereby presented is somewhat abbreviated from the concluding portion of a long and interesting article by Professor Ward, given under the same title. The review of the historic progress of our knowledge of sexuality in fungi, and the present state of such knowledge, with the numerous illustrative diagrams are necessarily omitted for want of space.—EDS.

oospore—and the same is true for an egg, etc., the terms being different—simply a *renewal* of the growth of the organism; and from this and other convictions follows the result that the formation of an oosphere, although it may take place after an accumulation of large quantities of food, implies a condition of weariness—if the term may be allowed—on the part of the protoplasm for the time being. No doubt the molecular energy of the protoplasm forming the oosphere, is less than that of the rest of the plant for the time being; the access of the antherozoid or male protoplasm, however, reinvigorates the sluggish mass, and renewed life ensues. This may require some time, however, and we may possibly not be far wrong if we imagine that interval to be occupied in molecular rearrangements in the mass.

But, although we can sum up the foregoing by saying that, after a time, protoplasm requires reinvigorating by the addition of fresh protoplasm from another source, it is extremely improbable that the protoplasm of the male and female organs is at all similar.

It now remains to be seen if we can throw any light on the curious disappearance of sexual organs and sexuality in the Fungi—curious, because the sexual process appears to be all but universal in all organisms excepting the very lowest.

A hypothesis which suggests itself, and which Eidam[1] favors, and which is certainly supported by some analogies, is to the effect that the apogamous Fungi, *i. e.*, those in which the sexual organs are totally suppressed, are not always apogamous. We know that many forms only produce their sexual organs at comparatively long and rare intervals. The *Mucors*, for instance, may be propagated through numerous generations by means of the asexual spores; the sexual organs only arising now and again under favorable conditions.

Moreover, the cases of polyembryony—where several embryos arise in an embryo sac, although only one oosphere is fertilized—favor the view that the effect of fertilization may be extensive; and we can not doubt that such is the case where adventitious covering branches arise after the conjugation of certain *Mucorini*, and in the *Orchideæ*, where fertilization or even the mere growth of the pollen tube affects the whole flower.

The sexual act, however, consisting as it does simply or mainly in the reinvigoration of protoplasm by the addition of protoplasm of a different nature (though we do not know the kind or limit of difference), it may be that an explanation of what occurs

[1] Cohn's Beitr. zur Biologie, etc., B. iii, H. iii.

in the Fungi is afforded by their mode of life. The Fungi in which sexual organs seem to be most certainly absent are those which are most highly specialized as parasites. Now, we have every reason to believe, first, that parasitism is a matter of degree, and secondly, that the most highly specialized form of parasitism consists in directly obtaining those contents of the cells of the host which are chemically most complex, and therefore contain most energy.

I need not dwell on the degrees of parasitism exemplified by plants which merely rob their hosts of space or moisture, or which have obtained a hold so intimate that they break it up and feed on the rotting *debris*, but may at once pass on to consider a few consequences which follow from the mode of life of those highly specialised parasites which have become so closely adapted to their host, that they exist for a time as all but an organic part of its tissues and substance.

It can scarcely be doubted that the protoplasm of a higher plant, such as a phanerogam, differs from that of a lower cryptogam in being capable of doing more work, and that the great advantage derived by a parasitic Fungus which has its life so adapted that it can tax the cells of a phanerogamous host plant, is that it contains its food materials in a condition more nearly approaching that of its own substance, than would be the case if it had to work these materials up from inorganic matters.

Now it seems not improbable that the protoplasmic substance of a higher phanerogam may contain so much energy that it can not only supply the vegetative mycelium of a parasitic fungus with all that it requires for its immediate growth, but also suffices to enable that fungus to store up enough energy in its asexual or apogamous spores to last until the next generation of the fungus gains its holdfast on another (and it may be distant) source of life-giving substance.

Let us take the case of a uredinous fungus parasitic in the leaves of a phanerogam. We know that the substances necessary for the whole growth of the phanerogam are formed in the cells of the leaf; not only so, the matters which eventually find their place in the reproductive organs must be formed there also, potentially at least. The leaf of a phanerogam so attacked, moreover, is able to support the parasitic fungus for a long time uninjured, as I have convinced myself by experiment, and there can be no doubt that substances pass into the fungus which would normally have passed into other parts of the host plant itself.

But we may imagine even this to fail after a time—we may

suppose that at length the Fungus derives too little benefit to be able to go on; or the season during which the host plant flourishes is drawing to an end.

No doubt we have in heterœcism the salvation of such a Fungus. Not only is it carried through a dangerous period, by seeking relief at the hands of a second host, but—and which I believe to be far more important—it obtains reinvigoration by the new protoplasm with which it comes in contact. We may not inaptly compare the sojourn of the Fungus on its second host, to a trip to the seaside, where the weary and enfeebled organism enjoys fresh diet and associations for a time, which in their turn pall and prepare the recipient to renew old modes of life.

We have seen that the disappearance of the sexual organs, leading to apogamy, commences especially in the lower *Ascomycetes*, and it may be more than a coincidence that epiphytic forms, which show a tendency to produce one kind of spore while on the living leaf and develope their asci on the fallen leaf are common here; such forms suggest how the parasitism and heterœcism of higher forms may have begun, and it is remarkable that the apogamy becomes more and more complete as we ascend through the latter.

It is not pretended that the hypothesis embodied above at once explains all the cases possible, and it will be well to state a few of the difficulties at once. The *Basidiomycetes* I shall not dwell upon, since our knowledge of them is still very imperfect.

The difficulty may suggest itself to many that there are parasitic fungi—such as the *Peronosporeæ*—which nevertheless develop the sexual organs in the condition typical and perfect for the group to which they belong. I have already referred to the fact that many of these forms are really saprophytes, and that others break down and destroy the tissues of their hosts—clumsily killing their prey, and then feeding on the rotten mass—and have pointed out that this is a much less specialized form of parasitism than that of the higher Fungi and *Ustilagineæ*.

Nevertheless, the sexuality shows signs of disappearance in extreme members. De Bary[1] shows that in *Phytophthora* and *Peronospora* there is a less evident passage over of protoplasm from the antheridium to the oosphere than in *Pythium;* and that in some cases, indeed, the quantity passing over is too small to be observed. I will not attempt to lay stress on the coincidence that in *Phytophthora infestans* (the fungus of the potato disease) no sexual act has yet been discovered.

[1] Beitr. zur Morph., etc., der Pilze, iv, p. 72.

Another obvious objection may be raised as follows:—The *Saprolegniæ* are in the main saprophytes, and yet they are said to be advanced towards apogamy—parthenogenetic, at any rate. The answer may be that they are saprophytic chiefly on animal protoplasm, which contains more potential energy than does vegetable protoplasm. At the same time, some *Saprolegniæ* are parasitic on plants, and *S. ferax* now appears to be parasitic on fish[1].

I may say, in conclusion, that it was during the study of the parasitic fungus of the coffee disease (*Hemileia vastatrix*)[2] in Ceylon that I was first led to speculate on the enormous amount of energy displayed by an organism which shows not the remotest satisfactory trace of sexuality, but which reproduces itself through many generations exclusively by means of asexual spores. That this energy of reproduction is derived from the coffee tree there can be no doubt, and that it is at the cost of the reproduction of the host is sadly evident; the clear inference from the fact that the coffee leaf supplies substance for the reproduction, etc., of a fungus at the expense of its own fruit, is that the fungus takes matters which are very rich in energy, so rich, indeed, that the fungus is not necessitated to sort these substances in special reproductive organs, and to secrete sexual elements, one of which would then reinvigorate the other, but may employ them forthwith for the purposes of its own relatively simpler existence and reproduction.—*Quart. Jour. Mic. Sc*, April, 1884.

GENERAL NOTES.

Polarity of Lettuce Leaves.—The orientation of the leaves of *Lactuca Scariola*, which has made it one of the two best known "compass" plants, is repeated in a less degree in the leaves of the common garden lettuce. The polarity is scarcely apparent until the lettuce begins to throw up the flowering stem. It is very weak in the curled and wrinkled varieties, but it is well marked in the Cos varieties, which have flat narrow leaves much like the wild *L. Scariola*. The observation was made on over one hundred varieties of lettuce grown the present season in the garden of the New York Agricultural Experiment Station.—J. C. A.

Hibiscus Moscheutos and H. roseus.—Dr. J. Guillaud, of Bordeaux, sends a pamphlet containing his investigations resulting in the identification of

[1] Prof. Huxley, 'Quart. Jour. Mic. Sc'., 1882. [It may be found upon otherwise healthy salmon, according to the investigations of Mr. George Murray. 'Science', IV, p. 27.—Eds.]

[2] ['Quart. Jour. Mic. Sc.', Jan. 1882; noticed and figured in 'Am. Nat.', July, 1882.—Eds.]